DOCUMENT RESUME

ED 228 054 SE 040 930

AUTHOR Schlenker, Richard M.
TITLE Engineering Water Analysis Laboratory Activity.
PUB DATE Apr 83
NOTE 23p.; Prepared in the Department of Arts and Sciences, Maine Maritime Academy.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Chemical Analysis; *Chemical Reactions; *Chemistry; *Laboratory Procedures; Postsecondary Education; Science Education; Science Experiments; Sludge; *Water; *Water Treatment
IDENTIFIERS *Boilers; Marine Education

ABSTRACT

The purposes of water treatment in a marine steam power plant are to prevent damage to boilers, steam-operated equipment, and steam and condensate lives, and to keep all equipment operating at the highest level of efficiency. This laboratory exercise is designed to provide students with experiences in making accurate boiler water tests and to provide expertise they will be expected to apply during cadet shipping and in future maritime employment. The exercise consists of four procedures, applicable to samples of water drawn from any source. These include: (1) total alkaalinity "A" reading; (2) chloride test; (salinity); (3) caustic alkalinity "B" reading; (4) colorimetric phosphate procedure; and (5) dissolved solids meter procedure. Background information is also provided. Topics addressed include why water treatment of marine engineering plant water is needed (breakdown of composition of seawater is provided); how water impurities cause deposits; mineral deposits, scale (any solid material found on boiler tubes or inside drums after water has been drained out), and sludge; chemistry of scale and scale prevention; chemical composition of boiler water suspended solids; water corrosion of boiler metal; theory of corrosion, discussing chemical reactions at the anode and cathode; other kinds of damage from corrision; and evaporator water problems. (JN)

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ENGINEERING WATER ANALYSIS LABORATORY ACTIVITY

By

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Richard M. Schlenker
Department of Arts and Sciences
Maine Maritime Academy
Castine, Maine 04420
April 1983

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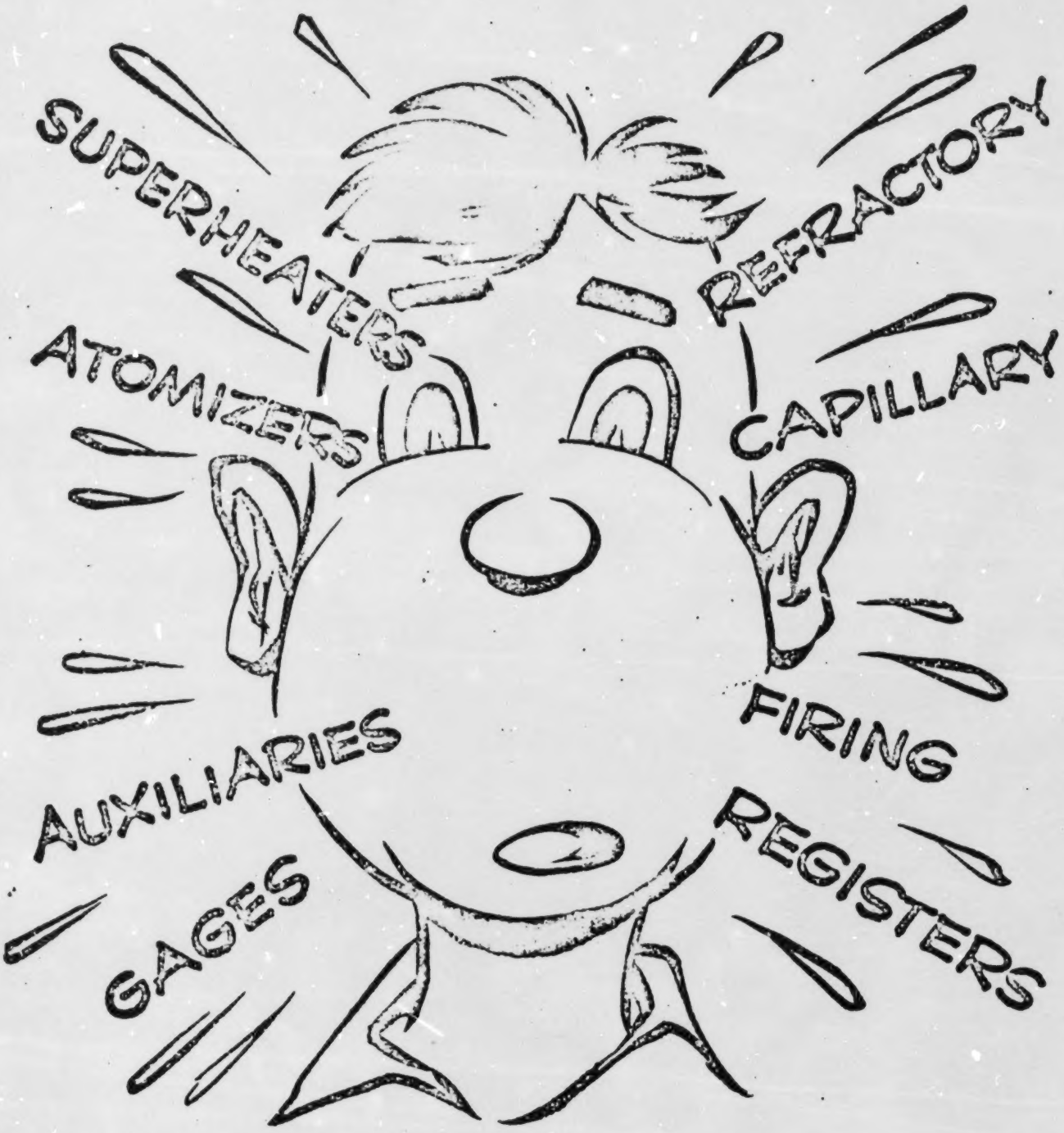
ENGINEERING WATER ANALYSIS

LABORATORY ACTIVITY



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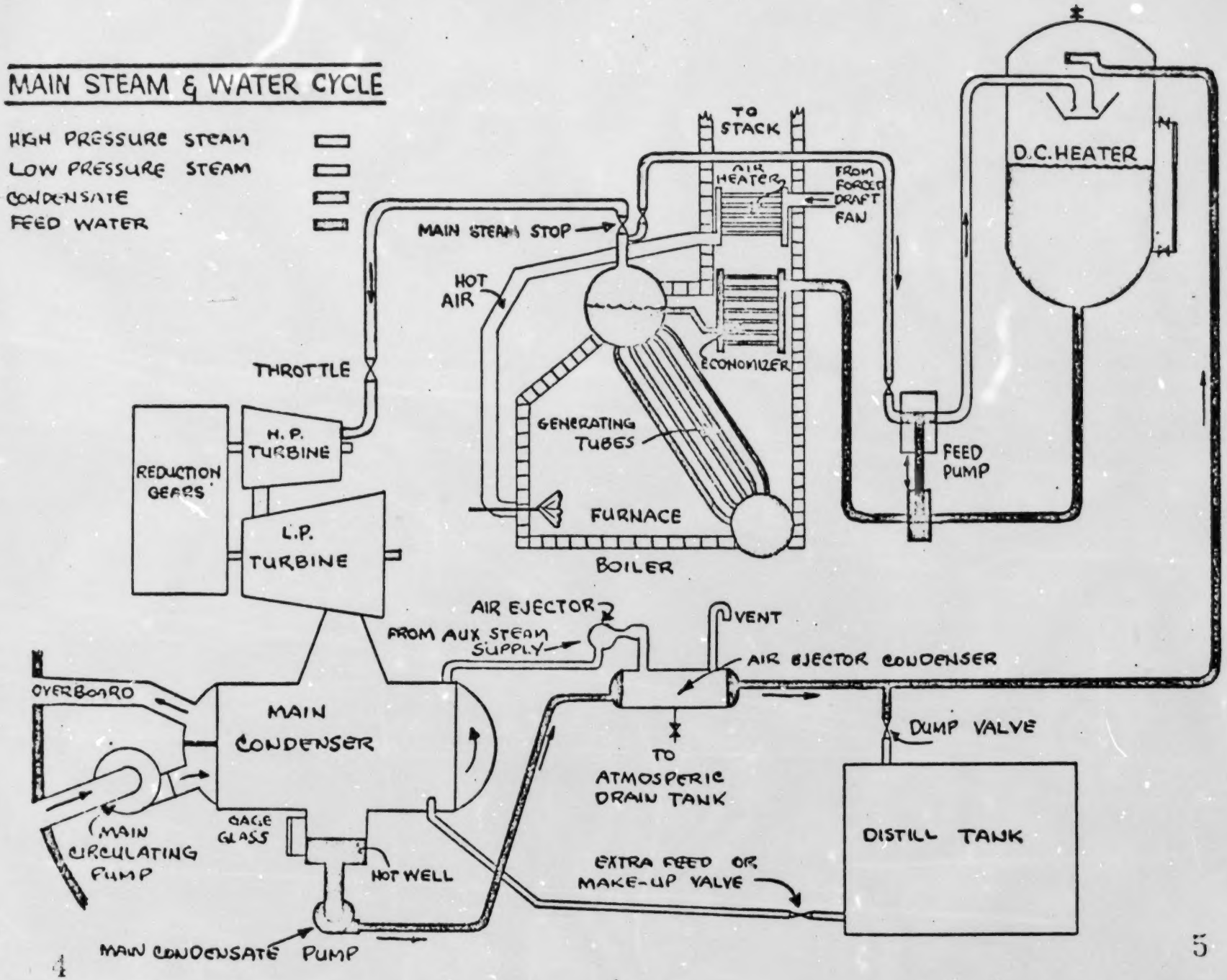
MAIN STEAM & WATER CYCLE
HIGH PRESSURE STEAM
LOW PRESSURE STEAM
CONDENSATE
FEED WATER
TO STACK
AIR HEATER
FROM FORCED DRAFT FAN
D.C. HEATER
MAIN STEAM STOP
HOT AIR
ECONOMIZER
THROTTLE
GENERATING TUBES
FEED PUMP
REDUCTION GEARS
H.P. TURBINE
L.P. TURBINE
FURNACE
BOILER
AIR EJECTOR
VENT
FROM AUX STEAM SUPPLY
AIR EJECTOR CONDENSER
OVERBOARD
MAIN CONDENSER
DUMP VALVE
TO ATMOSPERIC DRAIN TANK
MAIN CIRCULATING PUMP
GAGE GLASS
HOT WELL
DISTILL TANK
EXTRA FEED OR MAKE-UP VALVE
MAIN CONDENSATE PUMP

Objective: When students have completed this laboratory activity and the associated report, they should be able to conduct the following water analysis tests on samples of water drawn from any source. Those tests are: (1) Total alkalinity "A" reading; (2) Chloride test (Salinity); (3) Caustic alkalinity "B" reading; (4) Colorimetric phosphate procedure; (5) Dissolved solids meter procedure. Tests of this nature have been extremely well outlined by Bull & Roberts, Inc., Drew Chemical Corporation, and others.

Apparatus and chemicals:
2 - 50ml Graduated Cylinders
2 - 300ml Erlynmeyer Flasks
Filter Paper
Reserve Phosphate Comparator with Tubes
Total Dissolved Solids Meter
Phenolphthalein (Alkalinity Indicator)
.033 N H_2SO_4 (Alkalinity Test Solution)
Graduated Burette
Potassium Chromate (Chloride Indicator)
$AgNO_3$ (Chloride Indicator)
Barium Chloride Solution
Vanadoclomolybdate Reagent
0.1 H_2SO_4 (Total Dissolved Solids Reagent Solution)

Discussion: <u>WHY WATER TREATMENT OF MARINE ENGINEERING PLANT WATER IS NEEDED</u>

<u>The Composition of Seawater</u>:

Substance	Chemical Symbols	Amount, in* Parts per Million
	Metallic Ions (Cations)	
Sodium	Na^+	10,500 ppm (1.05%)
Magnesium	Mg^{++}	1,250
Calcium	Ca^{++}	400
Potassium	K^+	350
Strontium	Sr^{++}	14
	Nonmetallic Ions (Anions)	
Chloride	Cl^-	19,000 ppm (1.9%)
Sulfate	SO_4^{--}	2,700
Bicarbonate	HCO_3^-	140
Bromine	Br^-	70
Silica	SiO_2	10
Other(45 different substances)		16 ppm

Total dissolved matter 34,450 ppm (3.445%)

Most of the dissolved matter is in the form of ions. The sea water analysis shown above lists the various ions in the water. If the ions were combined to make compounds, the analysis would be approximately like this:

Sodium chloride - NaCL - 26,680 ppm
Potassium chloride - KCl - 1,220
Potassium bromide - KBr - 180
Magnesium chloride - $MgCl_2$ - 820
Magnesium sulfate - $MgSO_4$ - 3,380
Calcium chloride - $CaCl_2$ - 910
Calcium bicarbonate - $Ca(HCO_3)_2$ - 380

* One part per million is approximately equal to one milligram per liter. One percent is 10,000 parts per million.

WATER IMPURITIES CAUSE DEPOSITS

As feedwater enters a boiler, heat causes hardness (calcium and magnesium salts) to precipitate. Left untreated, the hardness will deposit on the hot boiler metal to form scale. As water evaporates in the boiler, the feedwater impurities concentrate. In higher pressure boilers, even small amounts of iron, copper, and silica can accumulate and cause serious deposit problems. Since scale can cause overheating and metal failure, preventive chemical treatment is needed.

MINERAL DEPOSITS, SCALE AND SLUDGE

Most marine engineers use the word "scale" for any solid material found on boiler tubes or inside drums after the water has been drained out. In water treatment, such material is called a *deposit*. There are two kinds of deposits - *scale* and *sludge*, formed in different ways, and different means are used to prevent their formation.

Once formed, both scale and sludge have the same effects: (1) they are both heat insulators, interfering with transfer of heat from the furnace to the water in the boiler; (2) most of the heat, not absorbed by the boiler water, goes up the stack, and the fuel that produced this heat is wasted. This loss of fuel efficiency is the *least* harmful result of a scale or sludge deposit; (3) Because of the insulating effect, mineral deposits prevent the boiler water from cooling the hot tubes and the metal becomes overheated and weakened. Such tubes often sag, or become blistered; (4) When large amounts of scale or sludge are formed, the deposits restrict the flow of water or completely plug a tube. This tube then becomes so overheated

that it swells and bursts; (5) Scale or sludge can cause corrosion of the boiler metal.

SCALE is a deposit, formed when minerals that have been dissolved in water precipitate on a metal surface. Makeup feed water may contain some or all of these scale-forming substances in solution.

1. Calcium	2. Carbonate
Magnesium	Bicarbonate
(These are called "hardness minerals".)	Hydroxide (also called "hydroxyl ion")
	Sulfate
	Silica

When water, containing scale-formers, comes in contact with the hot boiler tubes, scale deposits are formed. The minerals most often found in scale deposits are: (1) Calcium carbonate; (2) Calcium silicate; (3) Magnesium hydroxide; (4) Magnesium silicate; (5) Calcium sulfate (Sometimes formed when condenser leaks allow sea water to to get into the boiler feedwater.)

Scale is prevented by treating the water with chemicals that convert calcium and magnesium to suspended solids. When all the calcium and magnesium become suspended solids, scale cannot form.

The chemicals most often used for scale prevention in marine boiler water treatment are: (1) Sodium phosphate, used to convert dissolved calcium to calcium phosphate suspended solids; (2) Sodium hydroxide, used to convert dissolved magnesium to magnesium hydroxide suspended solids.

If there is *silica* in the water, it will be absorbed by the magnesium hydroxide.

Magnesium hydroxide becomes a scale deposit if it is formed by heat at the boiler tube surfaces. When sodium hydroxide is added as treatment, the magnesium hydroxide is formed in the *water* at a distance from the tubes, and is harmless.

It is important that the amounts of these chemicals, fed to the boiler, be measured and controlled accurately. When boiler water has been treated properly, it will contain small amounts of sodium phosphate and sodium hydroxide in solution. These are called "excess chemicals", because they are amounts that are fed in addition to what is needed to combine with the calcium and magnesium

CHEMISTRY OF SCALE AND SCALE PREVENTION

Scale deposition is, mainly, a result of the effect of intense heat at boiler tube surfaces on the mineral substances dissolved in the water.

Calcium carbonate: $Ca(HCO_3)_2 \xrightarrow{\text{Heat}} \underset{(\text{solid})}{CaCO_3} + CO_2\uparrow + H_2O$

Magnesium Hydroxide:

$$Mg(HCO_3)_2 \xrightarrow{\text{Heat}} \underset{(\text{solid})}{Mg(OH)_2} + 2CO_2\uparrow \quad \text{or,}$$

$$MgCO_2 + H_2O \xrightarrow{\text{Heat}} \underset{(\text{solid})}{Mg(OH)_2} + CO_2\uparrow$$

Note: Magnesium carbonate is not usually found in boiler scale, because it is much more soluble than calcium carbonate or magnesium hydroxide.

The solubility of Calcium sulfate decreases rapidly as temperature increases. Although it is more soluble than calcium carbonate, it may be deposited as scale if the alkilinity of the water is low and the sulfate content is high.

$$\underset{(\text{Solution})}{CaSO_4} + 2H_2O \xrightarrow{\text{Heat + excess } SO_4} \underset{(\text{solid})(\text{gypsum})}{CaSO_4 \cdot 2H_2O}$$

The mineral anhydrite (anhydrous $CaSO_4$) may be formed at very high temperatures. Silicates of calcium and magnesium may be formed when the water contains dissolved silica (usually in the form of silicic acid (H_2SiO_3). Many different silicate minerals have been found in boiler scales. Like other kinds of boiler scale, silicate scales can be prevented by properly controlled water treatment.

The chemistry of scale prevention is fairly simple. In general, chemicals are used to precipitate all the calcium and magnesium, quickly and completely, as soon as the feedwater enters the boiler. The precipitated matter, which is termed suspended solids, is relatively harmless.

Magnesium scale is prevented by adding sodium hydroxide, so that magnesium hydroxide is formed.

$$MgCl_2 + 2NaOH \longrightarrow \underset{(\text{suspended solids})}{Mg(OH)_2} + 2NaCl$$

The formula $CaCl_2$ is used only for convenience. The compound $Ca_5.(OH)(PO_4)_3$ preferred to other types of calcium phosphate, because it is less likely to adhere to metal surfaces that it may touch.

SLUDGE is any mineral deposit that is formed when suspended solids touch a metal surface and stick to it. Suspended solids are bits of solid matter so small that they are carried about by the water as it circulates through the boiler. These solids may be: (1) Iron oxide (rust) that is brought into the feedwater tank by the condensate; a result of corrosion of the steam and condensate return lines; (2) Solids formed inside the boiler when scale-forming minerals combine with treatment chemicals; (3) Mud or dirt that may be in the makeup water when fresh water from a lake or river is used for makeup. As the water moves along a metal surface, some of these small solids strike the surface. If the solids are hard, like small grains of sand, they usually bounce away. Solids that are soft and sticky, like mud, will probably form sludge deposits.

Build-up of sludge deposits is prevented by Blow Down.

Flash Blowdown from the bottom of the boiler removes solids that have settled out of the water. If they are not removed, these solids build up until they are like thick mud. If this mud is carried into the tubes by the circulating water, it will form thick deposits and may even fill the tubes, plugging them. Continuous blowdown from the top drum removes solids nearly as fast as they are formed. This keeps the amount of solids in the circulating water from becoming too large.

CHEMICAL COMPOSITION OF BOILER WATER SUSPENDED SOLIDS

Following is a list of the minerals most likely to be found in boiler water suspended solids.

Material	Composition	Source
Red Iron Oxide	Fe_2O_3	Corrosion of return lines or boilers.
Magnetic Iron Oxide	Fe_3O_4	Corrosion of return lines or boilers.
Copper Metal	Cu	Corrossion of return lines
Clay	Complex silicates of Al, Fe and Mg	Introduced by Contamination of feedwater with sea water or deck slops.
Calcium Carbonate	$CaCO_3$	Reaction product formed by heating water that contains calcium hardness.

Material	Composition	Source
Calcium Silicate	$CaSiO_3$	Reaction product from water that contains calcium and silica.
Tricalcium phosphate	$Ca_3(PO_4)_2$	Formed when water is overtreated with phosphate and undertreated with sodium hydroxide.
Hydroxyapatite*	$Ca_5(OH)(PO_4)_3$	Formed when proper treatment controls are maintained.
Magnesium hydroxide*	$Mg(OH)_2$	Formed when proper treatment controls are maintained.
Magnesium silicate*	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	Known as "serpentine". Formed in water that contains silica when proper treatment controls are maintained.
Magnesium Phosphate	$Mg_4(OH)_2(PO_4)_3$	Formed when water is overtreated with phosphate. This material is very likely to adhere to metal surfaces.
Oily sludge	-----	Formed when any of the above solids absorb oil.

*Starred items are minerals that may be produced as a result of chemical water treatment, and which are the least likely to form adherent sludge deposits. If there must be suspended solids in the boiler water, these are the preferred substances.

WATER CORRODES BOILER METAL

The corrosion of boiler system metal is a complex process and takes many forms: general attack, localized pitting, and various types of stress cracking. In general, the main factors causing boiler corrosion are dissolved gasses in the water (primarily oxygen) and extreme pH conditions. High temperatures accelerate the corrosion process. Corrosion is damaging from several standpoints: it generally causes weakening and metal failure and produces corrosion products, which can cause boiler deposits.

THEORY OF CORROSION

When water reacts with iron or steel in a steam boiler, the end products are magnetic iron oxide and hydrogen gas. The overall equation for this reaction is:

$$3Fe + 4\ H_2O \rightarrow Fe_3O_4 + 4\ H_2$$

The reaction takes place whenever water touches the very hot metal. Normally, the reaction occurs only at the surface of the metal, and stops as soon as the entire surface is covered with a film of magnetic oxide.

If anything happens that removes or destroys a part of this film, the reaction is repeated; thus, the film is renewed and the boiler is protected against corrosion.

If the film is, however, repeatedly damaged at the same place, or if anything prevents the reformation of the tightly adhering film, the water will continue to react with the metal (Fe_3O_4). Corrosion occurs and the metal may be penetrated very deeply. Dissolved oxygen can damage the protective film (Fe_3O_4).

$$2Fe_3O_4 + \tfrac{1}{2}\ O_2 \rightarrow 3\ Fe_2O_3$$

When a spot of ferric oxide (Fe_2O_3) forms on the metal, the restablishment of a contiguous film of magnetic Fe_3O_4 is prevented. Corrosion may then continue. For this reason, dissolved oxygen must be eliminated from boiler water.

Mineral deposits on the metal surface have a similar effect. Their presence on the surface prevents the establishment and maintenance of a uniform, contiguous, magnetic oxide film.

The reaction between iron and water is electro-chemical in nature. An area of exposed metal develops a positive electrical charge; it becomes an anode. Magnetic iron oxide is electrically "negative" with respect to iron metal; therefore, the oxide-coated metal adjacent to the exposed metal behaves as a cathode. An electric cell is established, and the following chemical reactions occur.

At the Anode:

(1) Atoms of iron go into solution as ferrous ions:

$$Fe \rightarrow Fe^{2+} + 2e-$$

(2) Ferrous ions react with water:

$$Fe^{2+} + 2\ H_2O \rightarrow Fe(OH)_2 + 2H^+$$

(3) Ferrous hydroxide is altered to magnetic oxide:

$$3Fe(OH)_2 \rightarrow Fe_3O_4 + 2H_2O + H_2$$

At the Cathode:

Electrons produced in (1) migrate through the metal to the cathode. Hydrogen ions produced in reaction (2) migrate through the water to the cathode. Then:

$$2H^+ + 2e- \rightarrow H_2$$

These reactions continue until: (1) The exposed metal is completely covered with a film of magnetic iron oxide, and/or; (2) the cathodic area absorbs so much hydrogen gas that it can no longer function as a cathode. (The cathode is then said to be polarized.)

Either of these effects will stop the reaction, but if neither takes place, the electro-chemical process continues and the metal becomes corroded.

We have seen how either dissolved oxygen or mineral deposits can interfere with the establishment of a magnetic oxide film. Oxygen can also prevent polarization of the cathodic areas by reaction with the hydrogen on the surface of these areas:

$$H_2 + \tfrac{1}{2} O_2 \rightarrow H_2O$$

This is another way in which oxygen can promote the corrosion of metal. This last process is not confined to steam boilers; it also occurs in diesel cooling systems, or anywhere that water which contains oxygen is in contact with iron or steel.

The chemistry of oxygen removal by means of chemicals is fairly simple. The reaction with sodium sulfite is:

$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4$$

This reaction is rapid and complete at boiler water temperatures.

The reaction with Hydrazine is:

$$N_2H_4 + O_2 \rightarrow 2H_2O + N_2$$

Hydrazine also aids in restoring the magnetic iron oxide film, when the film has been damaged by formation of ferric oxide:

$$N_2H_4 + 6\ Fe_2O_3 \rightarrow 4Fe_3O_4 + 2\ H_2O + N_2$$

Other types of boiler corrosion include stress corrosion cracking, caustic embrittlement, etc. They are caused by physical or mechanical phenomena, and so are not amenable to correction by simple chemical water treatment methods.

Some of the most important kinds of damage are: (1) Thinning of the tube metal; this is a result of corrosion that is continuous and even over a fairly large area of metal, and called general corrosion. Thin metal is easily overheated. When thin boiler tubes are overheated, the pressure increases and they may swell and burst; (2) Pitting occurs when only a small area of metal is corroded and a deep hole called a pit develops. Pitting corrosion is usually more rapid than general corrosion and if it is not sotpped, some of the pits may go all the way through the metal, causing leaks and loss of boiler water. When there are many pits close together, they may become connected. The effect on the metal is then the same as that of general corrosion.

Corrosion in boilers is prevented by adding chemicals to the boiler water, that combine with oxygen and make it harmless. Hydrazine or Sodium Sulfite may be used for this purpose and are often called oxygen scavengers. Hydrazine (N_2H_4) prevents oxygen from damaging boilers, and helps prevent corrosion in other ways. At boiler water temperatures, Hycrazine combines with dissolved oxygen to form water and nitrogen gas.

Hydrazine also helps in forming and maintaining the black magnetic iron oxide film that protects the boiler against corrosion. If there is any iron oxide or copper oxide in the feedwater, Hydrazine aids in preventing them from forming sludge deposits. The amount of N_2H_4, Hydrazine, needed to control corrosion is determined by a chemical test of the boiler water.

Sodium Sulfite (Na_2SO_3) may be used in boilers. At boiler water temperatures, sodium sulfite combines with oxygen and forms sodium sulfate. Na_2SO_4 adds to the dissolved solids in the boiler water. Because the dissolved solids in high pressure boilers should be kept low, sodium sulfite is not often recommended for high pressure work. Like Hydrazine, sodium sulfite changes red iron oxide to black magnetic iron oxide, but the change is too slow to be of help in preventing sludge deposits. Sodium sulfite dosage is controled by chemical tests.

Corrosion of condensate lines also causes serious problems. Corrosive condensate may eat through pipes causing leaks. Such leaks are found most often at threaded joints. When

leaks occur in gravity return lines or pipes under pressure, condensate is lost. Ship's evaporators may not be able to produce enough distilled water to keep up with such losses. This could make it necessary to stop a vessel at sea, or to have it proceed to the nearest port for repairs.

Corrosion of condensate return lines is caused mainly by dissolved carbon dioxide (CO_2) in the condensate. Carbon dioxide is formed when water containing carbonates or bicarbonates is heated in the boiler. This gas leaves the boiler along with the steam. When steam condenses, some of the carbon dioxide dissolves in the condensate, forming a weak acid (carbonic acid) that, in turn, corrodes the metal of the return lines. Corrosive condensate may also damage any metal surface on which steam condenses. These include steam heating coils, condenser tubes, and any steam lines that are not properly lagged (insulated) to prevent loss of heat. When little or no dissolved oxygen is in the water, carbon dioxide causes general corrosion. Lines that are full of water most of the time will be corroded evenly all around and the corroded surface is smooth. A line that is only partly full most of the time may have a deep groove along its entire length. At the threaded ends of lines, the metal may be eaten away until the corrosion reaches the bottom of the thread cut. The metal that is left looks like short strips of wire. This is where most leaks occur.

If the condensate contains both carbon dioxide and oxygen, the corrosion will be either pitting or a combination of general corrosion and pitting. Air may be drawn into condensate lines through loose pipe joints, cracked valve bonnets, gasket seals in flanges, or through leaks caused by corrosion.

Part of the dissolved oxygen in the boiler feedwater may be carried out of the boiler with the steam. Although the amount is usually very small, if the deaerator is not working properly, there may be enough oxygen to cause trouble in the condensate lines.

If the condensate contains both dissolved oxygen and ammonia, it can corrode copper and copper alloys. Small amounts of ammonia do not corrode these metals when there is no oxygen in the water.

Condensate line corrosion is prevented by use of chemicals that combine with carbon dioxide and make it harmless. Hydrazine is one such chemical. Others that are often used are called Amines. Such chemicals are fed to the boiler

where the heat changes them to gases that leave the boiler with the steam. When steam condenses, the chemicals dissolve in the condensate. These are basic chemicals. Acids and bases combine with each other to form salts and water. Chemists say they neutralize each other. Acids, like the carbonic acid that is formed when carbon dioxide dissolves in condensate, may dissolve or corrode metals. The chemicals that are formed when acids and bases combine do not corrode metals.

Part of the Hydrazine fed to the boiler for oxygen control becomes a vapor that dissolves in condensate when the steam condenses. Hydrazine is a basic and, therefore, will neutralize carbonic acid and prevent corrosion. At high temperatures, heat may cause a chemical change in Hydrazine. Nitrogen gas and ammonia gas are formed. Ammonia is also basic and will neutralize carbonic acid.

When sodium sulfite is used for oxygen control, amines are used to prevent steam and return line corrosion. These basic chemicals neutralize carbonic acid in the same way as Hydrazine or ammonia.

When condensate has been properly treated, it contains a small "excess" of the basic treatment chemical. There are several different ways of testing condensate to see whether it contains enough treatment chemical. One simple and convenient test is made by adding Phenolphthalein to a sample of condensate. If the sample turns pink, it is basic.

Evaporator Water Problems

Every kilogram of sea water contains about 35g dissolved minerals. When the water is evaporated, all these solids are left in the evaporator. Some of the dissolved solids are scale-formers. When the water is heated, scale and sludge deposits form on the evaporator coils. The large amount of salt and other minerals can cause the sea water to foam when it is heated. This causes carryover, which contaminates the distilled water.

Scale and sludge deposits in evaporators can be controlled by salinity control and chemical treatment. Salinity control refers to the continuous removal of evaporator brine in order to limit the amount of solids in the evaporator.

Chemical treatment helps to prevent scale-forming minerals from adhering to the coils. Two types of chemicals are used.

"Antiprecipitating agents", which keep the scale-formers in solution. Sludge conditioning chemicals like those that

are used to prevent sludge deposits from forming in boilers.

POOR QUALITY WATER GIVES POOR QUALITY STEAM

High concentrations of dissolved and suspended matter in boiler water can cause foaming at the steam release surface. This produces carryover of the water and its impurities into the steam. Carryover results in deposits, corrosion, and contamination in superheaters, turbines, and other processes using steam. While mechanical and operational factors also cause carryover, proper control of water conditions is important in producing good-quality steam.

Boiler water treatment

The purposes of water treatment in the marine steam power plant are: (1) to prevent damage to the boilers; (2) to prevent damage to steam-operated equipment, and to the steam and condensate lines; (3) to keep all equipment operating at the highest efficiency.

PURPOSE: The purpose of this lab is to provide students with experience making accurate boiler water tests, and to provide with expertise they will be expected to apply during cadet shipping and in future maritime employment. By taking boiler water tests frequently, marine engineers get an indication of what is taking place in a ship's engineering water system. Such data is used to prevent troubles before they occur.

By conducting water analysis tests daily, engineering plant water related problems may be prevented. If there is any slight indication of trouble, the tests should be conducted more frequently. Water samples should be drawn from a point where a true representation of the boiler water may be obtained. The sample line should be fitted with a cooler to cool the sample so that it does not flash to steam upon being drawn. Flashing causes a reduction of sample size, higher chemical concentration, and false high readings. Samples should be cooled to room temperature, and drawn into glassware that has been thoroughly rinsed with the samples being tested.

There are three units students may encounter in boiler water testing. They are: (1) PARTS PER MILLION (PPM) is a weight per weight unit that indicates the number of parts of a specific substance to a million parts of another substance. For example: 1 lb salt to 1,000,000 parts water is a 1ppm concentration of salt. 5 lbs. salt to 1,000,000 parts water is a 5ppm concentration.

(2) EQUIVALENTS PER MILLION is the number of equivalent parts of a specific substance to 1,000,000 equivalent parts of another substance where equivalent means the chemical equivalent weight of the substance. Example: The chemical equivalent weight of sodium chloride is 58.5 so a solution of 58.5 parts NaCl to 1,000,000 parts water has a concentration of 58.5 parts per million or 1 equivalent per million.

(3) PH VALUE. Ships with 1200 psig boilers use ph value rather than alkalinity. The ph number indicates the degree of alkalinity but does not give the amount of alkalinity in ppm or epm. Ph values range from -1 to 15 with 7 being neutral. Above 7, the solutions are alkaline and below 7, acidic.

Students will use ppm in this lab. The Bull & Roberts test kit is used on many ships. In this lab, the procedures are used as they are written in Bull & Roberts Boiler and Feedwater Conditioning Principles and Practice. When conducting these tests, the following points should be remembered:

1. Obtain proper samples of the boiler water.
2. Use chemicals which are not dated.
3. Make all measurements and readings as accurately as possible.

4. Keep all test equipment clean and in good working order.

PROCEDURES: Conduct each of the following tests.

I. Total Alkalinity - "A" Reading.

A. Measure 50 ml of the cooled sample of boiler water in the graduated cylinder and transfer to the 300 ml flask which has been cleaned and rinsed in the boiler water sample. Add 5 or 6 drops of Alkalinity Indicator. The sample should turn red.

B. Fill the Alkalinity Test Solution burette to the zero mark. Allow the Test Solution to flow drop by drop into the flask, with gentle swirling until the red color just disappears. Read the burette at the top of the solution and record this as the "A" reading in mls.

Save this neutralized sample for the chloride test.

II. Chloride Test (Salinity)

A. Add three or four drops Chloride Indicator to the sample saved from the first (I) experiment. The sample should turn yellow.

B. Fill the Chloride Test Solution burette to the zero mark. Allow the solution to flow drop by drop, with gentle swirling, until the yellow color JUST changes throughout the sample to a reddish yellow color. WARNING: Many students tend to overtitrate this sample. Take your reading just as the entire sample turns color. Record this reading in ml as chlorinity. The reading in mls can be converted to grains per gallon by multiplying by 2 or to ppm by multiplying by 34.2. The sample may now be thrown away and the flask carefully rinsed.

III. Caustic Alkalinity - "B" reading

A. A second 50 ml sample is now measured into a 300 ml flask. Add 5 or 6 drops Alkalinity Indicator plus 5 ml Barium Chloride Solution. If no red color develops, the "B" reading is zero.

B. Titrate drop by drop into the flask from the refilled Alkalinity Test Solution until the red color just disappears. Record the burette reading in mls as the "B" reading. Swirl solution with each drop.

IV. Colorimetric Phosphate Procedure

A. Fold a new dry filter paper into the funnel. Always use a new piece or the readings obtained will be false. Filter the sample into the square 5-10 ml viewing tube until it is almost full. Pour out excess water until you have 5 mls. Add 5 ml Vanadomolybdate Reagent into the tube. Cap the viewing tube with your finger and invert 2 or 3 times. Allow to set fo- three minutes, and place this tube into the right square hole in the top of the comparator.

B. Fill the second square tube to the 5 ml mark with distilled water. Add 5 ml of the reagent to the tube. This is your standard for comparison. Place the tube into the left side of the comparator.

C. Now match the colors as viewed through the lens. Record the reading on the indicator window in ppm as the Reserve Phosphate. Use a white background for viewing.

V. Total Dissolved Solids Meter.

A. Turn the range selector switch to test and depress the operating button. Turn the measuring dial until balance is obtained.

B. Draw a cool sample of boiler water and measure out 25 - 30 ml into a flask and add 2 - 3 drops of Alkalinity Indicator. Titrate with TDS Reagent Solution until the pink color just disappears.

C. Pour this sample into the conductivity cell until it is almost to the top. Insert the thermometer into the cell and note the temperature. Set the temperature compensation dial to this reading and remove the thermometer. Set the range dial to "Boiler Water" and push the operating button while turning the measuring dial until the needle balances in the center. Release the operating button and read the TDS under the hairline. Record this value. Detach the cell and clean it with distiled water.

Helpful Knowledge:

The following states examples of how to treat boiler water. This is merely a guide and not to be used on board ship, as each ship usually has a chart of the proper treatments for that ship.

Low alkalinity -

Water Capacity of Boiler (tons)		Desired Increase in "A" or "B" reading, ml.			
		0.5	1.0	1.5	2.0
7		3.5	7.0	10.5	14.0
8	Ounces	4.0	8.0	12.0	16.0
9	of	4.5	9.0	13.5	18.0
10	Caustic Soda*	5.0	10.0	15.0	20.0
12		6.0	12.0	18.0	24.0
14		7.0	14.0	21.0	28.0

* if soda ash is employed, use quantities one third (1/3) greater than shown for caustic soda.

High alkalinity - Most boilers can take alkalinities up to twice the desired readings. If the Alkalinity exceeds this, the boiler is usually blown down.

Reserve phosphate is low - Follow the chart below but also dissolve approximately 1 oz. caustic soda per 1/4 lb. phosphate to keep the alkalinity readings the same.

Water Capacity in Boiler (tons)		Desired increase in Phosphate Reading, ppm			
		10	20	30	40
8	Ounces of Marine Phosphate RS	1.5	3.0	4.5	6.0
10		2.0	4.0	6.0	8.0
12		2.5	5.0	7.5	10.0
15		3.0	6.0	9.0	12.0

High Reserve Phosphate - This reading should at no time exceed the normal reading by a factor of 2. If this should occur, blowdown is the only solution. High TDS readings - blowdown.

Operating Range for Boiler Water on The Training Vessel State of Maine -

Alkalinity:

"A" Reading	3.6ml to 4.8ml
"B" Reading	3.0ml to 4.0ml
Spread	0.6ml to 0.8ml

Reserve Phosphate:

Phosphate test	40 to 60 ppm

Chloride (Salinity)

Maximum	4ml = 8 grains per gallon (gpg)

Total Dissolved Solids

Maximum	300 ppm

Use these values as ranges of normal values when answering questions 2-7 on your lab report.

Lab Report

Total Alkalinity - "A" Reading _____ml

Chloride Test (Salinity) _____ml _____gpg _____ppm

Caustic Alkalinity - "B" Reading _____ml

Spread Between "A" and "B" Readings _____ml

Reserved Phosphate Reading _____ppm

TDS Solution Temperature _____^{o}C

Total Dissolved Solids _____ppm

1. What treatment would you prescribe for this boiler assuming it has a 10 ton capacity?

2. You perform boiler tests on an 8 ton capacity boiler.
   "A" Reading - 3.2ml
   "B" Reading - 2.5ml
   Reserve Phosphate - 50 ppm

   What treatment should be prescribed?

3. With a chloride reading of .6ml -
   A. What is this reading in gpg?

   B. What is this reading in ppm?

4. You have the following readings from a 10 ton boiler.

   "A" Reading - 3.8ml
   "B" Reading - 3.4ml
   Reserve Phosphate - 10 ppm

   What should you do?

5. A TDS reading is 350 ppm. What treatment should be prescribed?

6. You have an "A" reading of 10ml and a "B" reading of 9.3ml from an 8 ton boiler. What should you do?

7. You have a reserve phosphate of 120 ppm. What should you do?